Claims 1, 2, 4, 5 and 14 are all of the claims pending in the present Application. Claims 6-13 were previously canceled as non-elected claims, and claim 3 is canceled above.

Claim 14 is allowed, pending resolution of the issue raised by the Examiner that a new oath be provided. Claims 1 and 2 stand rejected under 35 USC §103(a) as unpatentable over US Patent 6,096,648 to Lopatin et al. Claims 4 and 5 stand rejected under 35 USC §103(a) as unpatentable over Lopatin, further in view of US Patent 6,037,664 to Zhao et al.

These rejections are respectfully traversed in view of the following discussion.

I. THE CLAIMED INVENTION

As described and claimed, the present invention is directed to a semiconductor device having an HSQ layer formed on a copper wiring line and having properties that copper is unlikely to enter the HSQ layer.

In a first embodiment, the copper wiring line is embedded in a layer of HSQ with an adhesion layer separating the two.

In a second embodiment, the copper is embedded in a PAE layer and HSQ layers formed above and below the PAE layer. The PAE layer reduces capacitance between copper wires and the upper and lower HSQ layers provide containment.

II. THE SUPPLEMENTAL OATH REQUIREMENT

The Examiner asserts that claim 14 represents a claim for subject matter not originally claimed or embraced in the statement of the invention and has required a supplemental oath or declaration under 37 CFR 1.67. Applicant respectfully traverses this characterization of claim 14. This claim reflects the second embodiment of the invention, as taught in Figure 7 and

described in the specification beginning at line 7 of page 15.

The advantage of this second embodiment is that the PAE layer reduces capacitance between copper wires and the upper/lower HSQ layers provide containment (see page 16 at lines 19-26). Applicant additionally respectfully asserts that original claim 1 "... an insulating layer which has a property that Cu is unlikely to enter said insulating layer and which insulates between said plurality of wiring lines" does indeed cover this second embodiment.

Accordingly, Applicant respectfully requests that the Examiner reconsider and withdraw the requirement for a supplemental oath or declaration under 37 CFR 1.67, and that claim 14 is thereby allowable.

III. THE PRIOR ART REJECTION

The Examiner asserts that US Patent 6,096,648 to Lopatin et al., further in view of US Patent 6,037,664 to Zhao et al., essentially teaches the invention as described by claim 1. The Examiner asserts that:

Lopatin et al. teach copper 24 and low dielectric constant layer, e.g., layer 30 including HSQ material thus possessing the property that Cu is unlikely to enter it since the same material is employed. The provision of via in low dielectric constant 50 followed by barrier layer 54 and copper is also taught. See column 6 line 4 to column 7 line 21. Although Lopatin et al. do not explicitly recite the Cu concentration to be equal to or higher than 10^{19} atoms/cm^3, such would have been encompassed in Lopatin et al. since the concentration therein is not required or limited to be below the said value, and since the optimization of such concentration to obtain a desired conductivity would have been obvious to one skilled in the art.

Claims 3-5 are rejected under 35 U.S.C. 103(a) as being unpatentable over Lopatin et al. as applied to claims 1 and 2 above, and further in view of Zhao et al.

Lopatin et al. as applied above show also the barrier but do not recite the adhesion language, the use of tungsten and the same etching rate.

Zhao et al. teach various the conventional use of liner in conjunction with copper wherein the barrier also provides adhesion, including the use of tungsten for such material. See column 4 lines 52 to column 5 line 25. -63. The provision of openings 24 and 25 in various low dielectric constant material, e.g., layer 14, followed by copper conductor, e.g.,

29 including barrier/adhesion is also shown. See column 6 lines 10 to column 8 line 45.

It would have been obvious to one skilled in the art at the time the invention was made in practicing the above invention to have included the tungsten barrier/adhesion layer in question to improve adhesion/barrier characteristic in the copper interconnect. The selection of the same etching rate would have been obvious and would have been within the purview of one skilled in the art to facilitate the removal of the wiring line and the adhesion /barrier layer.

Applicant respectfully disputes the Examiner's characterization of the primary reference, Lopatin et al., or that the concentration mentioned in claim 1 is insignificant.

First, as previously argued by Applicant, Lopatin does not teach or even suggest that HSQ provides protection against the diffusion of copper relative to other low dielectric constant materials. As clearly stated in Lopatin at line 66 of column 2 through line 2 of column 3, low dielectric constant material serves "to protect the copper lines from shorting or building up charges between the copper lines during operation", a statement true of any "low dielectric constant material". These phenomena are understood as being different from the diffusion of copper atoms into the low dielectric constant material, which the present inventor has discovered to become significant as separation between adjacent conductive copper lines becomes smaller and low dielectric constant material is used as a separation material.

That is to say, HSQ is not singled out as a preferred low dielectric constant material. Indeed, at lines 28-32 of column 6, Lopatin teaches various low dielectric constant materials as including HSQ, MSQ, BCB, FLARE, SILK, NANOGLASS, and FSG, and makes no distinction whatsoever.

In reality, MSQ and NANOGLASS are inorganic polymers. BCB and FLARE are organic polymers. According to Figures 3A and 3B of the present Applicant, neither inorganic polymers nor organic polymers provide protection against copper diffusion. Only HSQ

provides a measure of such protection, which feature is required at short separation distance.

Therefore, in listing inorganic polymers and organic polymers (which are ineffective to prevent copper diffusion) together with HSQ, Lopatin fails even to recognize the problem addressed by the present invention (diffusion of copper in low dielectric constant materials), let alone teach, suggest, or render obvious the solution provided by the present invention that HSQ provides protection even if the copper conductive material has density equal to or higher than 10^{19} atoms/cm^3.

Second, relative to the Examiner's comment that the concentration in claim 1 is insignificant, Applicant respectfully traverses this characterization by pointing to Figures 4 and 5 of the present Application. Figure 4 clearly shows that HSQ diffusion differs from that of the inorganic polymer by approximately one order of magnitude as distance increases beyond approximately 0.1 micron. Figure 5 clearly shows that, beyond approximately 50 nm, copper diffusion in HSQ is limited to approximately 10^{18} atoms/cm^3, which feature points to HSQ as being preferable as a low dielectric constant material as conductors are moved closer and closer together. The significance of the density being equal to or higher than 10^{19} atoms/cm^3 is that the copper lines, when HSQ is used as the low dielectric constant material separating copper conductors, can continue to have high conductivity even when separated by short distance, a feature not suggested in the Lopatin reference.

Additionally, in Figures 6 and 7 Lopatin, by embedding the copper 24 directly in contact with the low dielectric constant layer 20, clearly fails to teach the use of tungsten as an adhesion layer.

The Zhao reference fails to overcome the above-identified deficiencies in Lopatin. Specifically, at lines 11-12 of column 2, this secondary reference teaches against using HSQ as

preferable to an organic low dielectric constant film. Additionally, as previously pointed out in the previous Amendment, at lines 24-26 of column 5, the secondary reference specifically teaches against using tungsten W as an adhesion layer for copper conductors. The Office cannot simply ignore these *express* contrary teachings of the prior art (see MPEP 2145 X.C. "Lack of Suggestion To Combine References" and 2145 X.D.2. "References Cannot Be Combined Where Reference Teaches Away from Their Combination").

Hence, turning to the clear language of the claims, there is no teaching or suggestion of "... a plurality of wiring lines which are formed of Cu whose concentration is equal to or higher than 10^{19} atoms/cm^3; an insulating layer which has a property that Cu is unlikely to enter said insulating layer and which insulates between said plurality of wiring lines; and at least one adhesion layer formed in an interface between said plurality of wiring lines and said insulating layer, said at least one adhesion layer allowing said plurality of wiring lines and said insulating layer to adhere to one another", as required by claim 1.

Relative to claim 4, the significance of an adhesion layer having the same polishing rate as the copper line is that the dishing and recess shown in Figure 10H is precluded during CMP (see disclosure at lines 18-20 of page 13). None of the references cited by the Examiner even mentions this problem, let alone provide the solution. Accordingly, the Examiner's position that such solution is obvious can only be considered as being impermissible hindsight.

For the reasons stated above, the claimed invention is fully patentable over the cited references.

Further, the other prior art of record has been reviewed, but it too even in combination with Lopatin et al. and/or Zhao et al. fails to teach or suggest the claimed invention.

IV. Formal matters and Conclusion

In view of the foregoing, Applicant submits that claims 1, 2, 5 and 14, all the claims presently pending in the application, are patentably distinct over the prior art of record and are in condition for allowance. The Examiner is respectfully requested to pass the above application to issue at the earliest possible time.

Should the Examiner find the application to be other than in condition for allowance, the Examiner is requested to contact the undersigned at the local telephone number listed below to discuss any other changes deemed necessary in a telephonic or personal interview.

The Commissioner is hereby authorized to charge any deficiency in fees or to credit any overpayment in fees to Attorney's Deposit Account No. 50-0481.

Respectfully Submitted,

Date: 8/29/02

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VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE CLAIMS:

Claim 3 has been canceled.

Claims 1 and 4 have been revised, as follows.

1. (Amended) A semiconductor device comprising:

a plurality of wiring lines which are formed of Cu whose concentration is equal to or higher than 10^{19} atoms/cm^3; [and]

an insulating layer which has a property that Cu is unlikely to enter said insulating layer and which insulates between said plurality of wiring lines; and

at least one adhesion layer formed in an interface between said plurality of wiring lines and said insulating layer, said at least one adhesion layer allowing said plurality of wiring lines and said insulating layer to adhere to one another.

4. (Amended) [The semiconductor device according to claim 3] A semiconductor device comprising:

a plurality of wiring lines which are formed of Cu whose concentration is equal to or higher than 10^{19} atoms/cm^3; and

an insulating layer which has a property that Cu is unlikely to enter said insulating layer and which insulates between said plurality of wiring lines; and

at least one adhesion layer formed in an interface between said plurality of wiring lines and said insulating layer, said at least one adhesion layer allowing said plurality of wiring lines and said insulating layer to adhere to one another, wherein said at least one adhesion layer has an etching rate which is essentially equivalent to an etching rate of said plurality of wiring lines,

wherein each of said at least one adhesion layer has [an etching] a polishing rate which is essentially equivalent to [an etching] a polishing rate of said plurality of wiring lines.